IS 5477-3 (2002): Methods for fixing the capacities of reservoirs, Part 3: Live storage [WRD 10: Reservoirs and Lakes]

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भाग 3 सक्रिय संचयन

(पहला पुनरीक्षण)

Indian Standard

FIXING THE CAPACITIES OF RESERVOIRS — METHODS

PART 3 LIVE STORAGE

(First Revision)

ICS 93.160

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

December 2002 Price Group 3

Dams and Reservoirs Sectional Committee, WRD 9

FOREWORD

This Indian Standard (Part 3) (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by Dams and Reservoirs Sectional Committee had been approved by the Water Resources Division Council.

Live or active and conservation storage is the space in the reservoir provided to impound water for drawal during period of low flows. Thus, this storage enables successful satisfaction of planned power, irrigation, domestic, industrial and other water use demands and minimum river flow requirements.

The standard was first published in 1969. This first revision of the standard has been taken up to incorporate the latest technological and other practices currently in vogue in this field.

There is no ISO Standard on the subject. This standard has been prepared based on data/practices prevalent in the field in India.

The composition of the Committee responsible for the formulation of this standard is given in Annex A.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, should be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

FIXING THE CAPACITIES OF RESERVOIRS — METHODS

PART 3 LIVE STORAGE

(First Revision)

1 SCOPE

This standard (Part 3) lays down the criteria for fixing the live storage capacities of reservoirs.

2 REFERENCE

The standard given below contain provisions, which through reference in this text constitute provisions of this standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below:

IS No.	*Title*
4410 (Part 6) : 1983	Glossary of terms relating to river valley projects: Part 6 Reservoirs (*first revision*)

3 TERMINOLOGY

3.0 For the purpose of this standard the following definitions in addition to those given in IS 4410 (Part 6) shall apply.

3.1 Water Demand

3.1.1 *Irrigation Demands*

It is the volumes of water needed at and from the reservoir for irrigation purpose in each 10 days, 15 days, monthly or yearly period for which the simulation is planned.

Generally, irrigation demands are worked out using crop water needs based on actual field data or modified Penmann approach, irrigation field efficiencies, conveyance efficiencies at field channel or water course, minor or major distributary, main canal, etc (including all losses). Total demands for command are further projected taking into account the crop calendar, cropping packages available in the agro climatic zone, irrigation intensities envisaged as also rate and extent of development anticipated. Leaching requirements are also covered at this stage.

For working out the total demand at the reservoir end, it is necessary to account for end use requirements, conveyance losses and ground water.

3.2 Demand for Navigation, Recreation, etc

It is the volume of water needed to maintain minimum navigational draft downstream and minimum discharge required for maintaining ecological balance in the downstream reach.

These water demands are worked out before the simulation exercise considering constraints on upstream level in order to maintain the health of the river and to keep it fit for navigation and recreation. Water demand prior to the construction of water resources project should also be considered in the simulation study to take care of economic, social and legal problems at the operation stage.

3.3 Power Demand

It is the volume of water needed at and from the reservoir to generate power using the planned power facility.

The output of power is estimated in the simulated study using the net head acting on the turbine and the envisaged discharge as per rating curve taking into account the efficiency of relevant generation unit. As simulation study needs to meet projected power demand in various scenarios, the load factor and envisaged load patterns need to match the generation demand. The duration, for which volume of water is calculated, may be diurnal, 10 days, 15 days, monthly or annual as is relevant to the simulation study.

3.4 Water Supply Demand

It is the volume of water needed for drinking and domestic use for a planned population projection envisaged to be catered to and may include distribution and other losses enroute. Such a projection may also include envisaged industrial uses and supplies either earmarked in bulk or to individual users.

3.5 Minimum Drawdown Level

It is lowest level at which the full release towards meeting the specified purpose is physically possible and allowable under operating instructions.

3.6 Net Annual Water Demand

It is the total annual water demand for different uses excluding evaporation losses from the reservoir.

4 GENERAL FACTORS FOR DESIGN OF RESERVOIRS

4.1 The annual dependable flow into the reservoir is decided after examination of variability of annual stream flows. If compared with the planned demand, it may indicate whether a stream is frequently deficient with respect to the estimated water demand in a particular reservoir project. Low flows may be augmented by reservoir storage. The effectiveness of a reservoir depends primarily upon the rate of withdrawal called reservoir draft *D*, reservoir storage capacity *S* and the time series structure of the stream flows. The relationship between the reservoir storage capacity, draft and the resulting reliability *R* called storage equation, and is represented as:

$$S = f(D, R)$$

In the reservoir design any two of these three variables can be considered as independent and assigned specific values. The value of the third variable may be computed from the storage equation for the given inflows input or available water series. There are several methods for the solution of storage equation and their selection would depend on the stream flows considered.

4.2 For fixing the storage capacities of reservoirs, the following data would be required:

a) Stream flow data at the site of interest or for upstream, downstream or nearby station for 25 to 40 years period,
b) Evaporation losses from the water-spread area and seepage losses,
c) Sediment data at or nearby sites,
d) Original elevation versus area and capacity curves, and
e) Water use demand.

4.2.1 Stream flows for 10 days, 15 days, monthly or yearly, assembled for period of 25 to 40 years, are needed for conducting the simulation exercise. These may be obtained from a historical record, if a station is functional or data collected at the project site or derived from the record of an upstream or downstream station or nearby station by suitable adjustment. Stream flow data of short duration are extended by synthesis from precipitation or from stream flow records of nearby and adjacent stations. Thus the needed input flow series required for simulation of reservoir operation and capacity fixation is assembled.

4.2.2 Reservoir or lake evaporation cannot be measured directly like rainfall or stream flow. It is necessary to estimate evaporation from lake or reservoir by water budget, energy budget, aerodynamic or pan-evaporation techniques. Considering simplicity and practicality, pan evaporation data collected locally are generally used for reservoir design purpose. For evaporation, the exposure of the pan has to be proper and devoid of distortions. In case such data are not readily available, these may be estimated from the records of existing reservoirs with similar characteristics. Latest monthly evaporation charts may be used for having an approximate estimate of evaporation. Generally reservoir evaporation is found to be about 0.67 to 0.81 times pan evaporation.

4.2.3 Seepage losses and ground water recharge may be suitably estimated until adequate data are obtained.

4.3 Planning must be carried out with a view to optimally utilize the resources in such a way as to ensure success of the project for at least 75 percent of the years in case of irrigation projects, 90 percent of the years in case of hydropower projects and 100 percent of the years for domestic and industrial water supply. These percentages may be relaxed in case of projects in drought prone areas.

5 METHODS FOR FIXING STORAGE CAPACITY

5.0 Of the various methods available, the mass curve method (*see* Fig. 1) permits alternative studies without much labour and is suitable for fixing an initial value, which may be refined in further studies. Graphical and numerical procedures are also available for fixing storage capacity of reservoirs.

5.1 Graphical Procedure

5.1.1 In case reservoir subject to an inflow *I* and an outflow *O*, the storage *S* at time *t* is mathematically defined as:

$$S_t = S_o + \int_0^t I\,dt - \int_0^t O\,dt$$

Plots of the cumulative sums *I* and *O* represent the inflow and outflow mass curves, respectively, with S_o being the initial reservoir storage. It can be seen in equation $S = f(D,R)$ that the reservoir storage capacity is the difference between the inflow and outflow mass curves. An example of this technique is shown in Fig. 2, in which the reservoir storage capacity *S* is determined for a constant demand *D* with the constraint that no failure is allowed during the design period. The procedure employs the concept of a semi-infinite (bottomless) reservoir and yields the required storage capacity as the minimum storage depletion recorded in an initially full reservoir during the design period. The following graphical procedure applies. The constant draft corresponds to a constant slope of the outflow mass curve *D*. A line parallel to *D* is drawn through each peak on the inflow mass curve *I*. The

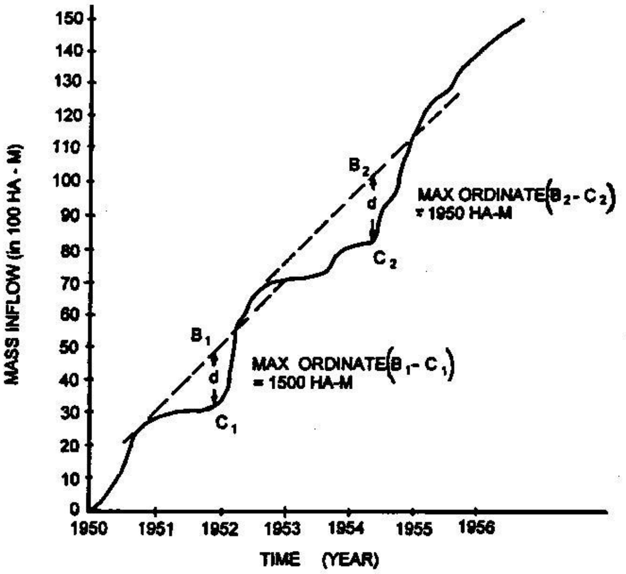

FIG. 1 MASS CURVE FOR DETERMINING RESERVOIR STORAGE CAPACITY

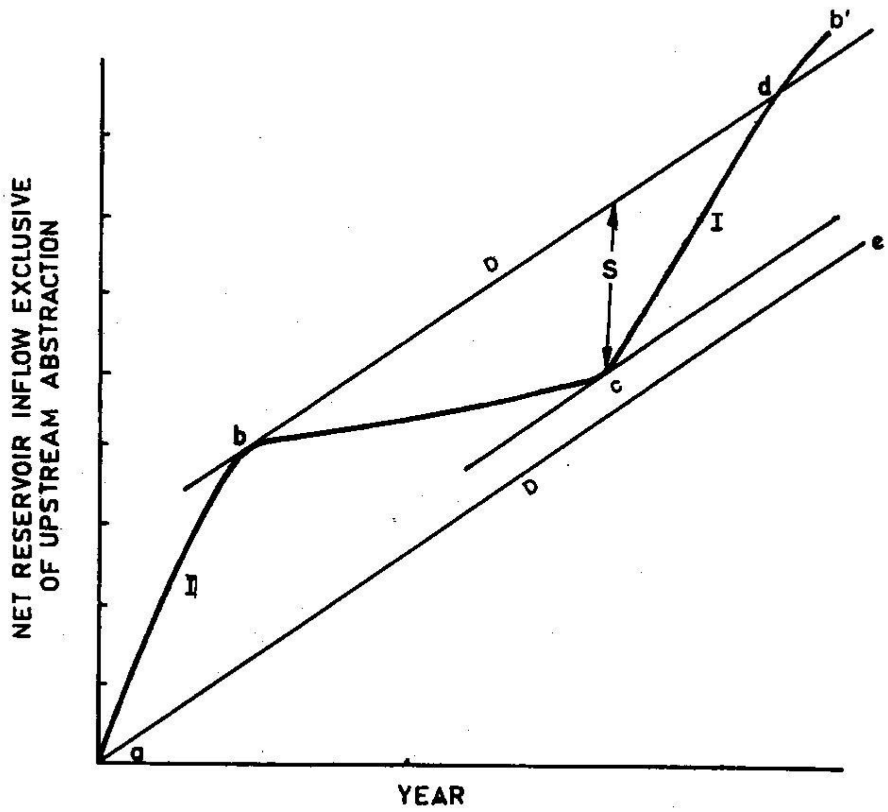

FIG. 2 SEGMENT OF NET INFLOW MASS CURVE

design storage capacity S is the maximum vertical distance between any point on I and the lines drawn parallel to D at each point.

5.1.1.1 The following information about the condition of the reservoir may be derived from the mass curve (*see* Fig. 2):

a) Inflow rate between *a* and *b* is more than the demand and the reservoir is full;
b) Reservoir is just full at *b* as the inflow rate is equal to the demand rate and thereafter the inflow rate starts falling;
c) Reservoir storage is being drawn down between *b* and *c* since the demand rate exceeds the inflow rate throughout the interval;
d) Draw down, S, is maximum at *c* as demand rate is equal to inflow rate and thereafter the inflow rate starts rising;
e) Reservoir is filling or in other words the drawdown is decreasing from *c* to *d* as the inflow rate is more than the demand rate; and
f) Reservoir is full at *d* and from *d* to *b'* again the reservoir is overflowing as the inflow rate beyond *d* is more than the demand rate. The greater vertical distance, S, at *c* is the storage required to meet the proposed demand.

5.1.2 When the demand is not uniform, numerical procedure should be used for fixing storage capacity.

5.1.3 *Estimation of Demand Likely to be Satisfied with a Given Live Storage Capacity*

The net inflow mass curve is prepared from available records and demand lines are drawn at peak points of mass curve such that maximum ordinate between the demand line and the inflow mass curve is equal to specified active storage. Demand line shall intersect the mass inflow line when extended forward. The slope of the flattest demand line indicate the firm demand.

5.2 Numerical Procedure (Simulation/Working Tables)

The numerical procedure is generally carried in a tabular form as shown in Table 1 or through computer software.

Assume that the reservoir has to cater for irrigation and the target demand of water for different periods (which may be months) is available. It is required that the success of the project should be for 75 percent of the years. The elevation-area-capacity table for the dam is available. A sufficiently long series of stream flows at the site are available. First, the upper and lower bounds on the capacity of the reservoir are to be fixed. The lower bound is usually the dead storage, which is required for sedimentation or due to position of outlet facilities. The upper bound can be determined from physical factors, such as water availability, etc, and should not be exceeded because of the danger of damage to shore property and to keep sufficient space for flood control purpose. A trial value for the reservoir capacity is selected which could be the mean of upper bound and lower bound.

The computation may be carried out either with reservoir full at end of monsoon period or for the steady state condition where the initial storage is equal to the final storage at the end of the design period. The effect of this initial storage value will not be very significant if the inflow series for a long period is being used. In the steady-state case, the computations are first carried out with arbitrary initial storage and are then repeated with the initial storage set equal to the final storage obtained in the first run. The results from the second run represent the steady-state situation.

Starting with a suitable value of initial storage content, the reservoir is operated using the stream flow data. During any time period, the release is made equal to the demand if that much water is available in the storage. Otherwise whatever can be made available is released and the reservoir is said to have failed in that period. Thus, whenever the release of the full demand would require the storage to drop below S_{Min}, the release must be reduced to a rate that prevents violation of this constraint. Likewise, should large inflows cause the storage to rise above S_{Max}, the water must be spilled to prevent such a rise. The evaporation losses can be easily computed by multiplying the reservoir-surface area by the depth of evaporation.

Table 1 shows a segment of computation for a case where the minimum storage capacity S_{Min}, is $800 \times 10^6\ m^3$ and the maximum capacity S_{Max} is $1\,450.0 \times 10^6\ m^3$. Each row of the table represents the reservoir water balance for one period, or the solution to the continuity equation:

$$S_{t+1} = S_t + I_t - E_t - R_t - O_t \qquad \ldots(1)$$

where S_t, I_t, E_t, R_t and O_t represent, the storage inflow, evaporation, release and spill for the period t. The release equals the water demand D_t for the period t subject to the constraint $S_{Min} \leq S_t \leq S_{Max}$. In the Table 1, the demand varies with the period. The violation of the lower constraint is prevented by reduction of the outflow by the amount $S_{t,Min} - S_t$ which is registered as a water deficit. The violation of the upper constraint is prevented by increasing the

Table 1 Reservoir Working Table

(*Clause* 5.2)

Sl No.	Month and Year		Initial Storage m^3	Reservoir Level m	Inflow m^3	Evaporation m^3	Demand m^3	Release m^3	End Storage m^3	Spill m^3
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	June	1977	800×10^6	190.000	350×10^6	2.00	200×10^6	200×10^6	948×10^6	0.00
ii)	July	1977	948×10^6	192.000	400×10^6	3.00	150×10^6	150×10^6	1195×10^6	0.00
iii)	August	1977	$1\,195 \times 10^6$	201.000	820×10^6	2.00	140×10^6	140×10^6	1450×10^6	$.423 \times 10^6$
iv)	September	1977	$1\,450 \times 10^6$	205.000	500×10^6	2.00	160×10^6	160×10^6	1450×10^6	338×10^6
v)	October	1977	$1\,450 \times 10^6$	205.000	392×10^6	4.00	180×10^6	180×10^6	1450×10^6	228×10^6
vi)	November	1977	$1\,450 \times 10^6$	205.000	157×10^6	4.00	200×10^6	200×10^6	1403×10^6	0.00
vii)	January	1978	$1\,403 \times 10^6$	203.000	84×10^6	4.00	150×10^6	150×10^6	1333×10^6	0.00
viii)	February	1978	$1\,333 \times 10^6$	202.000	66×10^6	4.00	140×10^6	140×10^6	1255×10^6	0.00
ix)	March	1978	$1\,255 \times 10^6$	200.000	44×10^6	3.00	120×10^6	120×10^6	1176×10^6	0.00
x)	April	1978	$1\,176 \times 10^6$	198.000	40×10^6	3.00	100×10^6	100×10^6	1114×10^6	0.00
xi)	May	1978	$1\,114 \times 10^6$	197.000	37×10^6	2.00	100×10^6	100×10^6	1049×10^6	0.00

outflow by an amount $S_t - S_{Max}$ registered as a spill.

The above operation of the reservoir is carried out for the entire period of record. After completing the computations, the water deficits are used to compute the reliability q. If this reliability is less than the desired value, it means that the capacity of the reservior must be increased. If, however, the reliability comes out to be higher than the required limit, the size of the reservoir is bigger than what it should have been and hence a smaller size is attempted for further examination. The computations are repeated in this manner till the reservoir size which gives the required reliability is arrived at. Efficient computer softwares are available to do these computations. It may be seen that in this method, generation of hydroelectric power can also be easily considered.

It should be ensured that revised areas and capacities expected after half service time should be used in these studies [Sedimentation studies to determine revised area and capacity expected after half service time and New Zero Elevation (NZE) after feasible or expected service time may, however, be ignored if annual sediment flow into the reservoir is less than 0.1 percent of gross storage capacity of reservoir].

ANNEX A

(Foreword)

COMMITTEE COMPOSITION

Dams and Reservoirs Sectional Committee, WRD 9

Organization	*Representative(s)*
In Personal Capacity (*D-13, Swati Apartment, Patparganj, New Delhi 110092*)	SHRI M. S. REDDY (***Chairman***)
Bhakra Beas Management Board, Chandigarh	CHIEF ENGINEER DIRECTOR (DESIGN) (*Alternate*)
Central Board of Irrigation & Power, New Delhi	DR A. S. CHAWLA DR A. N. BHARGAVA (*Alternate*)
Central Soil & Material Research Station, New Delhi	DIRECTOR SHRI A. K. DHAWAN (*Alternate*)
Central Soil & Water Conservation Research and Training Institute, Dehra Dun	SHRI K. P. TRIPATHI
Central Water & Power Research Station, Pune	SHRI P. B. DEOLALIKAR
Central Water Commission, New Delhi	DIRECTOR (CMDD-NW&S) DIRECTOR (RESERVOIR OPERATION) (*Alternate*)
Consulting Engineering Services (I) Pvt Ltd, New Delhi	SHRI M. K. NARASIMHAIYA
Continental Construction Ltd, New Delhi	SHRI CHANDER VERMA
Gammon India, Mumbai	SHRI M. S. BISARIA SHRI R. D. VARANGAONKAR (*Alternate*)
Geological Survey of India, Shillong	SHRI G. K. KAISTHA SHRI R. N. SINGH (*Alternate*)
Indian Agricultural Research Institute (ICAR), New Delhi	DIRECTOR
Indian Institute of Technology, New Delhi	HEAD (CIVIL ENGINEERING)
Irrigation & Waterways Directorate, Government of West Bengal, Kolkata	SHRI H. P. CHAKRABARTI
Irrigation Department, Government of Maharashtra, Nashik	SUPERINTENDING ENGINEER (MD) EXECUTIVE ENGINEER (MD-4) (*Alternate*)
Irrigation Department, Government of Punjab, Chandigarh	CHIEF ENGINEER (RSDD) DIRECTOR DAMS (RSDD) (*Alternate*)
Irrigation Department, Government of Andhra Pradesh, Hyderabad	CHIEF ENGINEER (I & CAD) SUPERINTENDING ENGINEER (DAMS) (*Alternate*)
Irrigation Department, Government of Haryana, Chandigarh	CHIEF ENGINEER (PROJECTS) DIRECTOR (ENGINEERING) (*Alternate*)
Irrigation Department, Government of Uttar Pradesh, Roorkee	CHIEF ENGINEER (DAM DESIGN) SUPERINTENDING ENGINEER (DAM DESIGN CIRCLE 1) (*Alternate*)
Jaiprakash Industries Ltd, New Delhi	SHRI D. G. KADKADE SHRI NARENDRA SINGH (*Alternate*)
Kerala State Electricity Board, Thiruvananthapuram	SHRI GEORGE CHERIYAN
Karnataka Power Corporation Limited, Bangalore	SHRI P. R. MALTI KARJUNA SHRI S. M. CHEBBI (*Alternate*)
Narmada & Water Resources Department, Government of Gujarat, Gandhinagar	CHIEF ENGINEER (MEDIUM & MINOR) & ADDITIONAL SECRETARY SUPERINTENDING ENGINEER (CDO) (*Alternate*)
National Hydroelectric Power Corporation Ltd, Faridabad	SHRI K. S. NAGARAJA
North Eastern Electric Power Corporation Ltd, New Delhi	SHRI UTPAL BORA
Public Works Department, Government of Tamil Nadu, Chennai	ENGINEER-IN-CHIEF
Tehri Hydro Development Corporation, Noida	SHRI L. K. BANSAL
Water Resources Department, Government of Madhya Pradesh, Bhopal	SHRI A. K. RISHI DIRECTOR (DAMS) (*Alternate*)
BIS Directorate General	SHRI S. S. SETHI, Director & Head (WRD) [Representing Director General (*Ex-officio*)]

Member Secretary
SHRI R. S. JUNEJA
Joint Director (WRD), BIS